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CASE REPORT

Early cardiac unloading with ImpellaCP™ in acute myocardial infarction with ventricular septal defect

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Abstract

Despite a relative contraindication, mechanical support with Impella™ left ventricular assist device has already been described for ischaemic ventricular septal defect treatment, either as a bridge to surgery, as intraoperative mechanical haemodynamic support, or to ensure intraprocedural haemodynamic stability during device closure. We describe two cases of ventricular septal defect complicating acute myocardial infarction, where the percutaneous ImpellaCP was implanted early (differently than previously described) with the aim of preventing haemodynamic instability, while deferring surgical repair. We present a report of haemodynamic, echocardiographic, biochemical, and clinical data of two consecutive cases of ImpellaCP use, within a minimally invasive monitoring and therapeutic approach. In two cases of subacute myocardial infarction-related ventricular septal defect not amenable to percutaneous device closure, the use ImpellaCP was successful: it was followed by effective and rapid right and left ventricular unloading, by major haemodynamic instability prevention and protection from systemic venous congestion, from kidney and splanchnic organ failures. This allowed bridging to appropriately timed surgical repair. These cases suggest a potentially effective, clinically grounded strategy in the early management of ischaemic ventricular septal defect patients, with the aim of deferring surgery beyond the safer 7 days cutoff associated with a lower perioperative mortality.

Keywords Ventricular septal defect; Impella; Acute myocardial infarction mechanical complication; Left ventricular assist device; Acute heart failure

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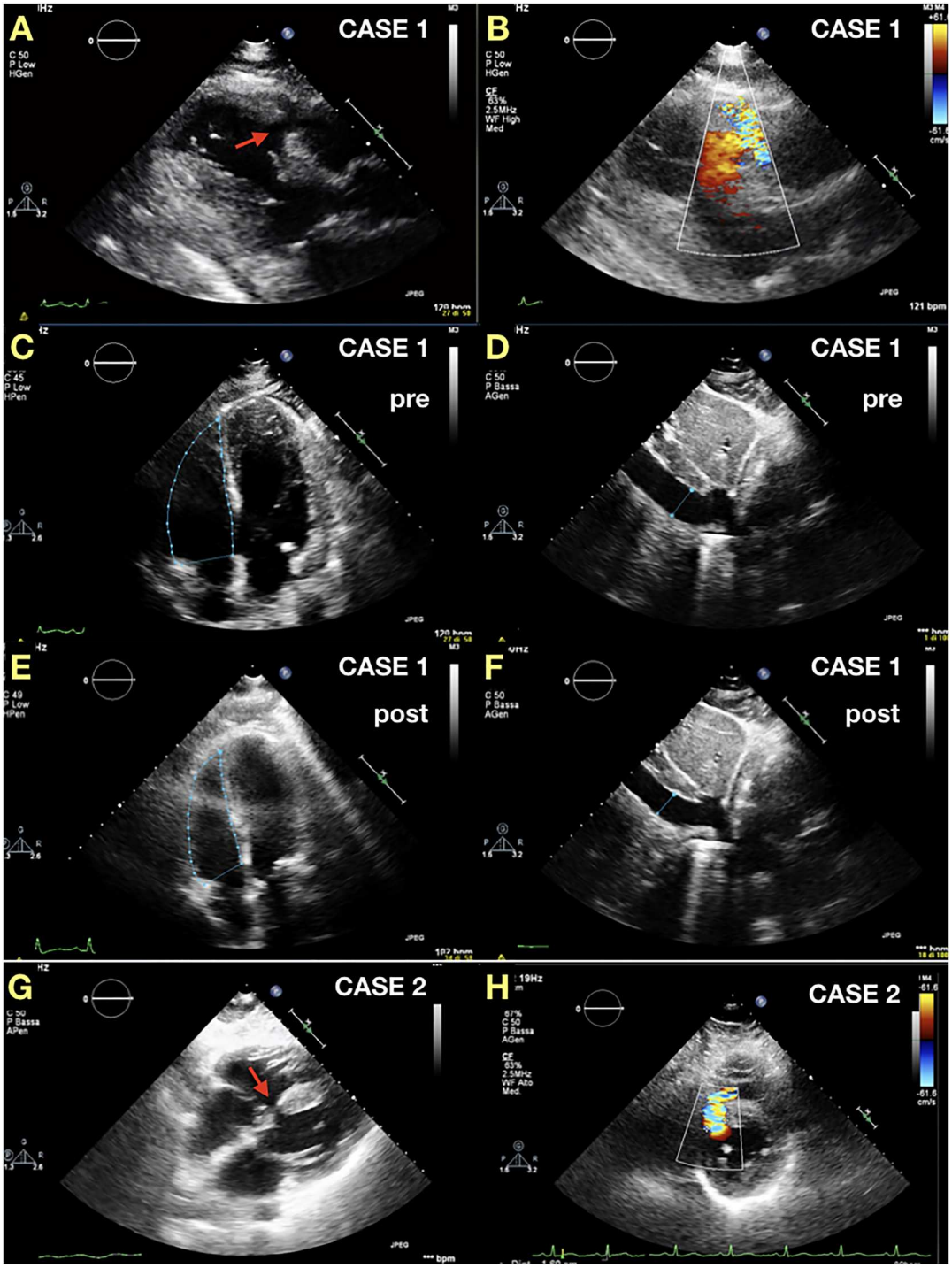
Introduction

Acute myocardial infarction (AMI) complicated by ventricular septal defect (VSD) is a life-threatening, rare complication (0.2–3%) of all AMIs,[1,2] burdened by an extremely high mortality (41–80%).[2] The urgency of defect closure conflicts with poor outcome due to surgery performed on a fragile, recently infarcted, myocardial tissue.[3] Perioperative traditional VSD management entails catecholamine infusion[4] and aortic counterpulsation. Recently, forms of mechanical haemodynamic support have been proposed.[5,6]

Although VSD is described as relative contraindication for the left ventricular (LV) coaxial heart pump Impella, its use has already been reported, so far in only nine patients, as an LV assist device to bridge to surgery in shocked/post-cardiac arrest patients[7,8] to ensure intraprocedural haemodynamic stability during device closure[9] and, intraoperatively, as a right ventricular assist device to aid weaning from extracorporeal circulation.[10,11] A very small case series indeed was weighed by high mortality when Impella was used in the context of advanced haemodynamic impairment. Besides intraprocedural applications, where Impella2.5™ (maximum 2.5 L/min flow, percutaneous access) was implanted, all other applications in the setting of VSD described a use of Impella5.0™ (max 5.0 L/min flow, surgical, axillary insertion).

In a recent computer simulation model, Impella was shown to effectively reduce both left-to-right shunt and LV filling

Figure 1 (A) Case 1: modified transthoracic echocardiography (TTE) parasternal long axis view showing mid-distal anterior ventricular septal defect (VSD, arrow). (B) Case 1: same TTE view, with left-to-right shunt portrayed as high-speed turbulent color jet through the VSD. (C) Case 1: apical 4 chamber view, end-diastole, showing a dilated right ventricle (RV). Measured RV indexed end-diastolic area was 13.4 cm^2/m^2. (D) Case 1: TTE subcostal inferior vena cava (IVC) view showing a dilated IVC (end expiratory diameter 22 mm). Inspiratory IVC size reduction was also measured as being 5%. (E) Case 1: same view as in panel C, immediately after ImpellaCP left ventricular assist device implant. RV size significantly reduced (measured RV indexed end-diastolic area was 10.6 $cm^2/m^{2)}$. (F) Case 1: same view as in panel D, immediately after left ventricular assist device implant. IVC end expiratory size significantly reduced to a size of 17 mm. IVC size inspiratory reduction also improved, becoming equal to 20%. (G) Case 2: TTE subcostal long axis view showing a basal inferoseptal VSD (arrow). (H) Case 2: TTE parasternal basal short axis view, showing a high flow turbulent left-to-right color flow through the inferobasal VSD.



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pressures in AMI-VSD, resulting as the optimal haemodynamic support.[12]

Case reports

We describe two cases of acute ischaemic VSD in which the percutaneous ImpellaCP™ (AbioMed Inc., Danvers, Massachusetts, USA; 3.8 L/min maximum flow, percutaneous insertion) was early implanted, in conditions of haemodynamic stability, to prevent cardiovascular deterioration and allow surgical repair delay to a safer time frame.

Patient 1

A 76-year-old woman with no antecedent medical history was admitted to the hospital because of worsening fatigue and dyspnoea for 5 days. Electrocardiogram (ECG) showed V1–V4 and D1 ST elevation and V3–V4 Q wave, consistent with subacute anterior ST-elevation myocardial infarction (STEMI). Troponin T at admission (hTnT) was 255 ng/mL. Echocardiography revealed a LV ejection fraction of 52%, (with apical and mid-anteroseptal akinesia, mid-anterior and basal anteroseptal hypokinesia), a dilated and hypokinetic right ventricle (RV) [indexed end-diastolic area 13.4 cm^2/m^2, tricuspid annular plane systolic excursion (TAPSE) 10 mm, fractional area change (FAC) 26%], and an estimated systolic pulmonary artery pressure of 45 mmHg. Further, a mid-distal anterior VSD (15 × 15 mm size), with significant left-to-right shunt flow, and caval plethora [inferior vena cava (IVC), 22 mm diameter, 5% inspiratory collapsibility) were found. (*Figure 1* and *Table 1*)

Haemodynamic and respiratory parameters were stable at intensive care unit (ICU) admission (blood pressure 142/107/90 mmHg, synus rhythm 105 b.p.m., lactates 1.4 mMol/L, SvCO2 76%, SpO2 97% with O2 2 L/min). ImpellaCP was implanted, and flow rate was maintained at 2.5–2.8 L/min (P6–P8). One hour after ImpellaCP implant, RV and IVC sizes reduced (indexed end-diastolic area 10.6 cm^2/m^2, IVC diameter 17 mm, 20% collapsibility), RV function improved (TAPSE 15 mm, FAC 32%), and central venous pressure (CVP) decreased (from 13 to 8 mmHg) (*Figure 1* and *Table 1*). Coronary angiography revealed an occluded left anterior descending artery that was left untreated because of the 5-day delay from symptoms onset, the absence of ECG signs of ongoing ischaemia, and the presence of an evident necrotic corresponding myocardium.[4] hTnT peaked on Day 1 (327 mcg/L), consistently with the evolution of a non-reperfused subacute STEMI. ImpellaCP was kept for 8 days. During this period, haemodynamics remained stable with no need of inotropes nor mechanical ventilation. N terminal proBNP (NT-proBNP) level decreased from 12 275 (before ImpellaCP) to 10 840 (first day after ImpellaCP) and to 7303 pg/mL (fifth day after ImpellaCP); renal and hepatic functions were preserved (Supporting Information, *Table S1*). No signs of major neurological dysfunction were observed. Surgical repair with pericardial patch and ventriculoplasty were performed successfully on Day 8. She was discharged from the ICU on post-operative day (POD) 3 and from hospital on POD 10. The 6-month follow-up was recorded free of further events, with a New York Heart Association class I, normal hepatic and renal function tests, and a functional capacity corresponding to >4 metabolic equivalents of task.

Patient 2

An 86-year-old man with previous recurrent pulmonary embolism (last episode was 30 years before, currently under oral anticoagulants) presented to the emergency department

Table 1 Cardiovascular and echocardiographic parameters before and after ImpellaCP left ventricular assist device implant, demonstrating right ventricular overload reduction

	CASE 1		CASE 2	
	PRE	POST	PRE	POST
SAPm (mmHg)	107	89	88	76
CVP (mmHg)	13	8	17	9
HR (bpm)	105	102	87	72
iRVEDA ($cm^{2/}m^2$)	13.4	10.6	17.8	15.3
TAPSE (mm)	10	15	7	10
RV FAC (%)	26	32	10	18
IVC (mm)	22	17	28	27
IVCc (%)	5	20	7	18
SpO2 (%)	97	100	95	98
SVcO2 (%)	76	80	50	67

CVP, central venous pressure; FAC, fractional area change; HR, heart rate; IVC, inferior vena cava; IVCc, IVC collapsibility index; iRVEDA, indexed right ventricular end-diastolic area; RV, right ventricle; TAPSE, tricuspid annular plane systolic excursion; SAPm, mean systemic arterial pressure; SVcO2, central venous oxygen saturation.

with dyspnoea and relapsing retrosternal typical pain for 4 days. ECG showed V2–V3 ST depression, DII, DIII, aVF ST elevation and Q waves, consistent with subacute inferior AMI. hTnT at admission was 1085 ng/mL. Echocardiography revealed mid-basal inferior and inferoseptal akinesia, ejection fraction > 60%, a dilated and hypokinetic RV (apical 4 chamber indexed end-diastolic area 17.8 cm^2/m^2, TAPSE 7 mm, FAC 10%), estimated systolic pulmonary artery pressure 40 mmHg, and a basal inferoseptal VSD (20 × 15 mm size) with relevant left-to-right shunt flow, caval plethora (IVC 28 mm, 7% inspiratory collapsibility) (*Table 1*).

Haemodynamic and respiratory parameters were relatively stable at ICU admission (blood pressure 123/88/70, heart rate 87sinus, lactates 1.79 mMol/L, SvCO2 50%, SpO2 95% with O2 3 L/min). ImpellaCP was then implanted percutaneously, and flow rate maintained at 3-3.4 L/min (P8). One hour after ImpellaCP implant, RV and IVC sizes reduced (indexed end-diastolic area 15.3 cm^2/m^2, IVC size 27 mm, 18% collapsibility), RV function improved (TAPSE 10 mm, FAC 18%), and CVP decreased (from 17 to 9 mmHg). Low dose dobutamine (3 mcg/kg/min) was then started, and RV systolic function further improved (TAPSE 13 mm, FAC 20%); SVcO2 also increased to 67% (*Table 1*).

Coronary angiography showed 100% occlusion of the mid-right coronary artery as culprit vessel, which was not treated, because of the subacute nature of AMI and absent ECG left and right signs of ongoing ischaemia.[4] hTnT peaked on Day 1 (1438 mcg/L). ImpellaCP was kept for 7 days. The patient did not require mechanical ventilation. The NT-proBNP level decreased from 27 072 (before ImpellaCP) to 9127 (first day after ImpellaCP) and 8020 pg/mL (fifth day after ImpellaCP); renal and liver function improved along with improvement of RV function (Supporting Information, *Table S1*). Neurological course was uneventful. Surgical VSD pericardial patch repair was uneventfully performed 7 days later. The patient was discharged from ICU on POD 12 and from hospital at POD 30, following respiratory and physical rehabilitation. At 6 months, he is still alive, with normal hepatic and renal function tests, New York Heart Association class III and a functional capacity corresponding to <4 metabolic equivalents of task.

Discussion

ImpellaCP is currently indicated for both elective and emergent high-risk percutaneous coronary interventions in the setting of LV dysfunction. It has also been adopted for LV unloading in STEMI patients without cardiogenic shock prior to percutaneous reperfusion, to reduce the ischaemia reperfusion injury and overall myocardial damage by myocardial preconditioning.[13]

We herein report for the first time a novel early use of ImpellaCP (before haemodynamic decompensation) in post-AMI VSD patients. Selection criteria of the two patients for this short-term percutaneous mechanical support were age > 75 years, unfavourable septal anatomy for device placement, and absence of severe peripheral vascular disease, a mechanical aortic valve, more-than-mild aortic stenosis, and LV mural thrombi. In both cases, VSD location and/or rim were not amenable to percutaneous device therapy.[14] The goal was to unload the LV and the RV and to safely defer surgery in order to allow for myocardial recovery and for stabilization of the infarcted, ruptured tissue. The immediate clinical, haemodynamic and echocardiographic improvement upon ImpellaCP implantation suggests that this early mechanical support significantly contributed to postpone surgery to the optimal time frame, protecting the patients from the risk of cardiovascular deterioration and venous congestion. Echocardiography showed rapid RV size and IVC size reduction, consistent with RV effective unloading. Patient 2 also required inotropic support (low dose and short term, according to current guidelines[15]) to achieve a satisfactory optimization, possibly due to preexistence of RV systolic dysfunction. In both cases, the NT-proBNP reduction and absence of liver and kidney function deterioration confirmed the reduction in systemic venous congestion.

The overall approach was conducted by minimizing invasive interventions. Daily transthoracic echocardiography allowed adequate monitoring of cardiac function and ImpellaCP correct position and function. The placement of ImpellaCP requires no surgery, and the patients were not intubated, nor developed subsequent respiratory or haemodynamic deterioration requiring intubation. The absence of haemodynamic deterioration waved the need of more invasive cardiovascular monitoring than invasive blood pressure, CVP, and indirect indices of global perfusion. Systemic anticolagulation was effectively conducted with intravenous non-fractioned heparin infusion (15.000–27.000 UI/day), to prevent thrombosis of the Impella device. Sedation with dexmedetomidine was necessary for Patient 1 due to an episode of delirium and for both to achieve sufficient safe maintenance of the device position. After Day 2, both patients were enterally fed, with no side effects.

Of the so far reported cases of Impella use as bridge to surgery in VSD,[7,8] three patients out of six died, in the context of multiple organ failure. Both of our patients in the cases of early ImpellaCP implantation suffered no splanchnic organ failure and survived, despite the older age (81 vs. 61.8 years average age).

Left ventricular (and subsequently RV) unloading is a mainstay of ischaemic VSD haemodynamic support.[16] Although Impella has not proven so far to be superior to intra-aortic balloon pump (IABP) in improving short-term outcome in post-AMI shock and in terms of cost effectiveness,[17,18] its pronounced LV unloading effect has been experimentally well

demonstrated as reduction in LV end-diastolic volume, left atrial volume, mean left atrial pressure and, differently from IABP, preload.[19] Moreover, Impella has also shown to effectively reduce afterload, as compared with IABP, in patients supported with veno-arterial extracorporeal membrane oxygenation (ECMO),[20,21] the latter being in this context effective as percutaneous device for LV venting. Moreover, Impella provides the advantage of combining this unloading capability (greater than IABP, and potentially also than veno-arterial ECMO in the face of very poor LV systolic function) with the generation of an antegrade flow (conversely to peripheral veno-arterial ECMO retrograde flow; IABP can only increase cardiac output by improving the heart's native flow-generating activity). Overall, the relative contraindication to Impella use in VSD should be weighed in light of the pros/cons of alternative strategies and of patient's overall clinical conditions and history. These cases suggest in fact a potentially effective, clinically grounded strategy in the early management of VSD patients. This may be particularly important for VSD patients not amenable to more invasive forms of mechanical support such as peripheral veno-arterial ECMO, with the aim of deferring surgery beyond the safer 7 days cutoff associated with a lower perioperative mortality.[22] Further investigations are warranted before this approach to be suggested as the optimal strategy to manage VSD patients before surgical destination.

Conflict of interest

None declared.

Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Detailed clinical, biochemical, hemodynamic and major outcome data of both patient 1 (top) and patient 2 (bottom).

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